Production Of Propionic Acid From Syngas

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    1. Abstract

With an estimated world production of capacity of 377,000 metric tons in 2006, Propionic Acid is an important organic acid that does not receive much publicity. Propionic Acid – which occurs naturally in apples, strawberries, grains, cheese, and human sweat – is mainly used as a mold inhibitor for various animal feed and baked goods as well as a preservative in cheeses. It is also a significant precursor in many industrial processes such as pharmaceuticals, plastics, plasticizers, textile and rubber auxiliaries, dye intermediates, as well as flavorings and cosmetics. Our group has designed a chemical plant for the production of Propionic Acid with a projected output of 33,000 tons per year. The initial feedstock will comprise of Sygnas (a mixture of CO and H­2) and Ethylene, which will react in a process known as carbonylation in the presence of a catalyst to produce Propionaldehyde. The Propionaldehyde will then be oxidized to produce Propionic Acid. The market demand for Propionic Acid is expected to grow at around 2.3% per year regardless of the state of the economy since food production and preservation is highly dependent upon it. With a steadily increasing market price and demand for Propionic Acid along with its marketability in other industrial processes combined with its high price relative to our cheaper reactants and catalysts should make the proposed plant a very economically feasible one.

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   * 1. Commercial Production

Propionic Acid – which occurs naturally in apples, strawberries, grains, cheese, and human sweat – is mainly used as a mold inhibitor for various animal feed and baked goods as well as a preservative in cheeses. It is also a significant precursor in many industrial processes such as pharmaceuticals, plastics, plasticizers, textile and rubber auxiliaries, dye intermediates, as well as flavorings and cosmetics.

* + 1. Environmental Review

As responsible engineers it becomes necessary to become concerned not only with how much money a process will be able to make but also with safety measures as well. Safety for the workers in the plant and safety for the environment, with the latter being the focal point of this section. Engineers have an ethical responsibility to ensure that in their efforts to improve the quality of life for mankind that a paradox is not created.

Industrially, the majority of Propionic Acid is used as a bactericide and fungicide to protect hay and grains that are being stored as well as an ingredient for pesticides. This is possible because it has been EPA certified to have low toxicity to fish, invertebrates, birds and mammals. Propionic acid is used primarily indoors and use outdoors in small amounts, when used outdoors, Propionic acid was metabolized by organisms into harmless components and has thus been deemed not harmful to the environment. Propionic acid is non-mutagenic and has overall been observed to not be harmful. Contact with concentrated solutions of Propionic acid however, may cause damage to eye and bodily membranes as the solution is corrosive. Protective clothing should be used when handling the compound in its purer forms.

Propionaldehyde is the intermediate product produced in the two step reaction and while it is only available in small amounts in the final product it is still necessary to know as much about this as possible. Propionaldehyde, according to the EPA, is not a carcinogen, nor does it have any reproductive effects on humans. Chronic effects: adverse effects on the body with symptoms that develop slowly due to prolonged exposure to something harmful and do not subside once the exposure is no more, are not associated with exposure to Propionaldehyde. Acute effects on the other hand, adverse effects that subside once exposure is terminated, results have proved to be inconclusive in the human though animals have shown moderate to acute toxicity to the substance.

Nickel Carbonyl: Although Nickel Carbonyl is an industrial standard for the carbonylation of ethylene it is a very dangerous substance. EPA classifies Propionic Acid as group 2B – Probable Human Carcinogen and the OSHA Permissible Exposure Limit (PEL) is 1 part per billion. Sulfur poisons this class, but we are requiring that team Foxtrot remove as much Sulfur as possible.

Rhodium is a very rare platinum group element. It is combustible in dust when in the powder form. Rhodium is quite toxic if inhaled, though this will not be a problem as the Rhodium based catalyst will be used on graphite supports and immobilized in a packed bed. It is good that very little handling of Rhodium will be necessary as it is also a skin irritant. There are very strict regulations as how to dispose of Rhodium. As Rhodium is a very rare element is it unknown whether or not it is harmful to the environment, and is not currently classified as harmful to the environment.

A Cobalt catalyst is used in the oxidation of Propionaldehyde to Propionic acid. Cobalt Iodide generally has a low toxicity; however, there are acute and chronic effects when exposed to larger amounts of Cobalt iodide. Acute effects include: shortness of breath, systemic effects, skin irritation, eye irritation, and cornea damage. Chronic effects include: respiratory sensitivity, nodular fibrosis, thyroid disease, pimples, boils, black and blue spots, hives, and blisters. The probability of these effects occurring is minimal as contact with the chemical is extremely limited and controlled. Operation of Cobalt Iodide will not be performed without safety clothing and a breathing apparatus.

* + 1. Specifications to Meet Industry Standards

The industry standard for Propionic acid is currently to have a 99.5 mol% purity. In order to achieve this goal the product will be separated many times throughout the process before the reaching a distillation column in which the final product will be obtained. The column was designed around the basis of having a 99.5% purity of Propionic acid.

* + 1. Clear Statement of Feedstock

The feedstock to be used in this process is synthesis gas made by team Foxtrot and Ethylene obtained from Lyondell Basell. The synthesis gas or syngas will be created from coal obtained from Illinois coal basin number 6 in southern Il. Because coal is being used as a source for syngas, the coal will have to be heavily treated in order to have it meet the specifications of the process. Desulfurization and CO2 sequestration are only two of the processes that take place in the purification of syngas in order to obtain a 1:1 mole ratio of CO to H2. The conditions at which the syngas will be delivered will be…

The other feedstock for the synthesis of propionate is ethylene. It will be obtained by pipeline an industrial standard purity. It will be obtained at 420 psig and 70 °F which is near the conditions of the reaction.

Oxygen will be fed into the second reaction which is the oxidation of Propionate to Propionic acid. Oxygen will be obtained from the air around and thus is assumed to be at ambient conditions.

* + 1. Engineering Design Standards

1. Block Flow Diagram
2. Process Flow Diagram
3. Material and Energy Balances
4. Calculations
5. Annotated Equipment list

|  |  |
| --- | --- |
| Equipment Piece | Description |
| Reactor 1 | Produces Propionaldehyde from Syngas and Ethylene |
| Reactor 2 | Oxidizes Propionaldehyde to Propionic Acid |
| Compressor |  |
| Cooler (HX) |  |
| Heat (HX) | Heats Oxygen entering the system in order to carry out the oxidation reaction |
| Heater (HX) | Heats the propionaldehye stream leaving the flash separator, before it enters the oxidation reactor |
| HX (HX) | Cools oxidized final product before it enters the distillation column |
| Flash | Separates Propionaldehyde from unreacted reactants before the Propionaldehyde can be oxidized |
| Dist- bottoms split | Used |
| Dist-cond | In big |
| Dist-cond acc | Flowsheet |
| Dist- reboiler | After the |
| Dist- reflux pump | Oxidation |
| Dist- tower | reactor |
|  |  |
| Cocat Separation |  |
| Cooler |  |
| decanter |  |
| Dist- bottoms split |  |
| Dist-cond |  |
| Dist-cond acc- horizontal drum |  |
| Dist- reboiler |  |
| Dist- reflux pump |  |
| Dist- tower |  |
| Heat |  |
| Separator |  |
|  |  |
|  |  |
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|  |  |

Chart VI.1

|  |  |  |  |
| --- | --- | --- | --- |
| Equipment Piece | E Cost | D Cost | Sizing |
| Reactor 1 |  |  | Liquid volume- 250 gal |
| Reactor 2 |  |  | Liquid volume- 250 gal |
| Compressor | 1140500 | 1236300 | Actual gas flow inlet – 4.18959 CFM  Driver Power- 1.4393386 HP  Specific Heat Ratio- 1.214862  Turbine gauge pressure – 300 Psig  Lube oil system- yes |
| Cooler (HX) | 15300 | 136600 | Heat Transfer area- 0.0688888 SF  Tube design gauge pressure- 325.3795 psig  Tube design temperature- 556.445 deg F  Tube operating temp- 506.445 deg F  Shell design gauge pressure- 212.021 psig  Shell design temp- 250 deg F  Shell operating temp- 95 deg F  Tube length extended- 20 feet  Tube wall thickness- 0.125 in  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- Triangular  Expansion joint- NO  Cladding location- Shell  # Tube passes- 2  # Shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vandor grade- High  Regulation Type- None |
| Heat (HX) | 8000 | 44900 | Heat transfer area- 3.2668 SF  Tube design gauge pressure- 110.304 psig  Tube design temp- 377.8 deg F  Tube operating temp- 327.8  Tube outside diameter- 1in  Shell design gauge pressure- 68.6373 psig  Shell design temperature- 250 deg F  Shell Operating temp- 122 deg F  Tube length extended- 20 ft  Tube wall thickness- 0.125 ft  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- triangular  Expansion joint- No  Cladding location- shell  # tube passes- 2  # shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vendor grade- high  Regulation type- none |
| Heater (HX) | 9600 | 57200 | Heat transfer area- 62.9533 SF  Tube design gauge pressure- 110.304 psig  Tube design temp- 377.8 deg F  Tube operating temp- 327.8  Tube outside diameter- 1in  Shell design gauge pressure- 68.6373 psig  Shell design temperature- 250 deg F  Shell Operating temp- 122 deg F  Tube length extended- 20 ft  Tube wall thickness- 0.125 ft  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- triangular  Expansion joint- No  Cladding location- shell  # tube passes- 2  # shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vendor grade- high  Regulation type- none |
| HX (HX) |  |  | Heat transfer area- 234.45499 SF  Tube design gauge pressure- 35.304 psig  Tube design temp- 2817 deg F  Tube operating temp- 2767 deg F  Tube outside diameter- 1in  Shell design gauge pressure- 60.304 psig  Shell design temperature- 250 deg F  Shell Operating temp- 95 deg F  Tube length extended- 20 ft  Tube wall thickness- 0.125 ft  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- triangular  Expansion joint- No  Cladding location- shell  # tube passes- 2  # shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vendor grade- high  Regulation type- none |
| Flash |  |  | Application: Standard continuous process vessel  Liquid Volume- 863.707858 gallons  Vessel diameter- 3.5 feet  Vessel tangent to tangent height- 12 feet  Design gauge pressure- 325.379475  Fluid volume- 20%  Design Temp- 1790.77608 deg F  Operating Temp- 1740.77608 deg F  Manhole diameter- 18 in  Allowance for internals- 0%  ASME design basis- D1NF  Start Stop cycles \* 1000- 5  Pressure cycles \* 100- 0  Pressure amplitude- 0%  # of hydrostatic tests- 20  Temperature cycles \* 1000- 0  Temperature amplitude- 0% |
| Dist- bottoms split |  |  |  |
| Dist-cond |  |  | Tube design gauge pressure- 150 psig  Tube outside diameter-1 in  Shell design gauge pressure- 150 psig  Tube seal type- seal welded tube joints  Tube pitch symbol- triangular  Expansion joint- No  Cladding location- shell  # tube passes- 1  # shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vendor grade- high  Regulation type- none |
| Dist-cond acc- horizontal drum | 15300 | 136600 | Application- standard continuous process vessel  Liquid Volume- 475.920655 gal  Vessel Diameter- 3 feet  Vessel Tangent to tangent length- 15 feet  Vacuum design gauge pressure- -14.696 psig  Design temp- 32 deg F  Operating temp- -386.630402 deg F  Manhole diameter- 18 in  # manholes- 1 |
| Dist- reboiler | 12500 | 59300 | Heat Transfer area- 95.5056  Tube design gauge pressure- 110.304 psig Tube design temperature- 377.8 deg F  Tube design operating temperature- 327.8 deg F  Tube outside diameter- 1 in  Shell design gauge pressure- 68.6373 psig  Shell design temp- 333.1601 deg F  Shell operating temp- 283.1601 deg F  Tube length extended- 20 feet  Tube wall thickness- 0.125 in  Tube pitch- 1.25 in  Tube pitch symbol- triangular  Cladding location- shell  # tube passes- 2  Duty- 0.48711 MMBTU/hr  Vaporization- 90%  Specific gravity tower bottoms- 0.5  Mol. Weight bottoms- 100  Heat of vaporization- 150 btu/lb  TEMA type- BKU |
| Dist- reflux pump | 4200 | 25300 | Casing material- Carbon steel  Liquid flow rate- 0.302487  Fluid head – 225 feet  Fluid specific gravity- 1.039488  Driver type- motor  Seal type- single mechanical seal  Design gauge pressure- 15 psig  Design temperature- 32 deg F  Fluid viscosity- 0.5 Cpoise  Pump efficiency- 70%  Steam gauge pressure 400 psig  Primary seal pipe plan- none  Secondary seal pipe plan- none  Cooling water pipe plan- none  Pipe plan pipe type- welded pipe/fittings |
| Dist- tower | 308300 | 489700 | Tray type- sieve  Application- distil  Vessel diameter- 1.5 feet  Vessel tangent to tangent height- 108 feet  Design gauge pressure- 15 psig  Design temperature- 333.160142 deg F  Operating temperature- 283.160142 deg F  Tray material- A285C  # Trays- 48  Tray spacing- 24 in  Cladding materials- none  Fluid volume- 20%  Jacket type- full  Jacket Material- Carbon Steel  Molecular weight product- 73.999443  Tray thickness- 0.1875 in  ASME design basis- D1NF (Division 1, no fatigue)  Start Stop cycles \* 1000- 1  Pressure cycles \* 100- 0  Pressure amplitude- 0%  # of hydrostatic tests- 20  Temperature cycles \* 1000- 0  Temperature amplitude- 0% |
|  |  |  |  |
| Cocat Separation |  |  |  |
| Cooler | 15100 | 74200 | Heat Transfer area- 330.859382 SF  Tube design gauge pressure- 35.304 psig  Tube design temperature- 600 deg F  Tube operating temp- 550 deg F  Shell design gauge pressure- 60.304 psig  Shell design temp- 250 deg F  Shell operating temp- 95 deg F  Tube length extended- 20 feet  Tube wall thickness- 0.125 in  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- Triangular  Expansion joint- NO  Cladding location- Shell  # Tube passes- 2  # Shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vandor grade- High  Regulation Type- None |
| Decanter | 15800 | 102400 | Liquid Volume- 634.560878 gal  Vessel diameter- 3  Vessel tangent to tangent diameter- 12 feet  Design gauge parameter- 15 psig  Vacuum design gauge parameter- -14.696  Design temp- 250 deg F  Operating temp- 122 deg F  Fluid volume- 20 %  Manhole diameter- 18 in  Allowance for intervals- 0  ASME design basis- D1NF (Division 1, no fatigue)  Start Stop cycles \* 1000- 1  Pressure cycles \* 100- 0  Pressure amplitude- 0%  # of hydrostatic tests- 20  Temperature cycles \* 1000- 0  Temperature amplitude- 0% |
| Dist- bottoms split |  |  |  |
| Dist-cond |  |  | Tube design gauge pressure- 150 psig  Tube outside diameter-1 in  Shell design gauge pressure- 150 psig  Tube seal type- seal welded tube joints  Tube pitch symbol- triangular  Expansion joint- No  Cladding location- shell  # tube passes- 1  # shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vendor grade- high  Regulation type- none |
| Dist-cond acc- horizontal drum | 12700 | 132900 | Liquid Volume- 475.920655 gal  Vessel Diameter- 3 feet  Vessel Tangent to tangent length- 9 feet  Design gauge pressure- 15 psig  Design temp- 32 deg F  Operating temp- -395.672712 deg F  Manhole diameter- 18 in  # manholes- 1 |
| Dist- reboiler | 30400 | 101900 | Heat Transfer area- 973.14504  Tube design gauge pressure- 110.304 psig Tube design temperature- 377.8 deg F  Tube design operating temperature- 327.8 deg F  Tube outside diameter- 1 in  Shell design gauge pressure- 68.6373 psig  Shell design temp- 324.642922 deg F  Shell operating temp- 274.642922 deg F  Tube length extended- 20 feet  Tube wall thickness- 0.125 in  Tube pitch- 1.25 in  Tube pitch symbol- triangular  Cladding location- shell  # tube passes- 2  Duty- 7.708059 MMBTU/hr  Vaporization- 90%  Specific gravity tower bottoms- 0.5  Mol. Weight bottoms- 100  Heat of vaporization- 150 btu/lb  TEMA type- BKU |
| Dist- reflux pump | 4200 | 26200 | Casing material- Carbon steel  Liquid flow rate- 9.816752  Fluid head – 225 feet  Fluid specific gravity- 1.164839  Driver type- motor  Seal type- single mechanical seal  Design gauge pressure- 15 psig  Design temperature- 32 deg F  Fluid viscosity- 0.5 Cpoise  Pump efficiency- 70%  Steam gauge pressure 400 psig  Primary seal pipe plan- none  Secondary seal pipe plan- none  Cooling water pipe plan- none  Pipe plan pipe type- welded pipe/fittings |
| Dist- tower |  |  | Tray type- sieve  Application- distil  Vessel diameter- 5.5 feet  Vessel tangent to tangent height- 78 feet  Design gauge pressure- 15 psig  Design temperature- 324.642922 deg F  Operating temperature- 274.642922 deg F  Tray material- A285C  # Trays- 33  Tray spacing- 24 in  Cladding materials- none  Fluid volume- 20%  Jacket type- full  Jacket Material- Carbon Steel  Molecular weight product- 73.114053  Tray thickness- 0.1875 in  ASME design basis- D1NF (Division 1, no fatigue)  Start Stop cycles \* 1000- 1  Pressure cycles \* 100- 0  Pressure amplitude- 0%  # of hydrostatic tests- 20  Temperature cycles \* 1000- 0  Temperature amplitude- 0% |
| Heat | 31400 | 124600 | Heat Transfer area- 1409.179665 SF  Tube design gauge pressure- 18.637333 psig  Tube design temperature- 650 deg F  Tube operating temp- 550 deg F  Tube outside diameter- 1 in  Shell design gauge pressure- 35.304 psig  Shell design temp- 650 deg F  Shell operating temp- 600 deg F  Tube length extended- 20 feet  Tube wall thickness- 0.125 in  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- Triangular  Expansion joint- NO  Cladding location- Shell  # Tube passes- 2  # Shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vandor grade- High  Regulation Type- None |
| Separator | 29000 | 183300 | Liquid Volume- 2132.829606 gal  Vessel diameter- 5.5 feet  Vessel tangent to tangent diameter- 12 feet  Design gauge parameter- 15 psig  Vacuum design gauge parameter- -14.696  Design temp- 600 deg F  Operating temp- 550 deg F  ASME design basis- D1NF (Division 1, no fatigue)  Start Stop cycles \* 1000- 5  Pressure cycles \* 100- 0  Pressure amplitude- 0%  # of hydrostatic tests- 20  Temperature cycles \* 1000- 0  Temperature amplitude- 0% |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| Heater | 8000 | 44900 | Heat Transfer area- 6.740545 SF  Tube design gauge pressure- 110.304 psig  Tube design temperature- 377.8 deg F  Tube operating temp- 327.8 deg F  Tube outside diameter- 1 in  Shell design gauge pressure- 68.637333 psig  Shell design temp- 250 deg F  Shell operating temp- 122 deg F  Tube length extended- 20 feet  Tube wall thickness- 0.125 in  Tube seal type- seal welded tube joints  Tube pitch- 1.25 in  Tube pitch symbol- Triangular  Expansion joint- NO  Cladding location- Shell  # Tube passes- 2  # Shell passes- 1  Weld Xray- 20%  TEMA type- BES  Vandor grade- High  Regulation Type- None |
| Mixer |  |  |  |
|  |  |  |  |

The information from the above chart comes from an Aspen Plus simulation which was sent to Aspen Icarus Process economic analyzer to determine sizing and costing of individual pieces of equipment.

E Cost- Equipment Cost

D- Direct Cost

1. Economic Evaluation factored from equipment cost

Propionic acid is used in many daily processes such as plastics and food preservatives and without it or an alternative to Propionic acid the quality of life would decrease. Propionic acid was chosen mostly due to its ability to preserve food and have it last longer. The longer shelf life that food has the more affordable it will become as food vendors will not have to throw away as much food, as their expiration times are increased by preservatives.

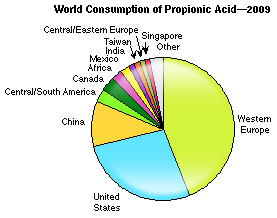


Figure ???: World Demand of Propionic Acid

In the above figure it can be seen that the United States is the second largest user of Propionic acid coming in second to Western Europe. As Western Europe is a region it can be inferred that the United States is the nation with the largest usage of Propionic acid. This information is encouraging to team Echo because it can be reasoned that because the U.S. is using so much Propionic acid that there must be a sizable demand for the product.

Figure ??? Price of Propionic Acid over the past decade

As can be seen in the above figure the price of Propionic acid has been steadily increasing over the past decade approximately doubling. This reinforces the idea that there is a great demand for Propionic acid. After all, with the increasing price and no decrease in the amount of Propionic acid used it can be inferred that it is very important and necessary. This is most likely due to the wide range of uses of Propionic acid. The relevance of establishing that there is a great demand for Propionic acid in this country is to determine the longevity of the project and whether or not it will pay out. The life of this project should be quite long as the demand for Propionic acid is not decreasing and is projected to rise over the next few years. As team Echo intends to target its sales towards food companies and the demand for food is always around without question, team Echo feels that this project will be profitable and long lasting.

|  |  |  |
| --- | --- | --- |
| Component | Price per year | Source |
| Ethylene | $ 14.7 million | Isis |
| Syngas | $5 million | Foxtrot |
| Cooling Water | $ 18,000 | Aspen |
| Catalyst price |  |  |
| Project Capital Cost | $ 62 million | Aspen |
| Estimated Operating Cost | $11 million | Aspen |
|  |  |  |
|  |  |  |

Table ???: List of Costing Material

If all 33,000 tons of Propionic acid is sold each year then the process will gross approximately $ 29 million per year. This yearly gross price in conjunction with all of the costs that will be incurred are used to establish a breakeven point. The sooner the breakeven point occurs the sooner that the process will start making money.

1. Utilities

The plant will require around ten workers. Each of these workers will be paid a base pay of $12/hr. Workers will have a maximum of 4 weeks of vacation time which does not roll over, thus if not used it will be lost. Workers will start will 1 week of vacation every year they will be evaluated as to whether or not they are permitted more paid vacation time.

In addition to these 4 weeks of vacation 5 sick days per year will also be given though In order to ensure that the plant is fully staffed at all times there will be four differing shifts that have been arranged so that there should be no overlap, and also so that there will always backup workers in case an absence should occur.

As leadership is always necessary one individual form each shift will be selected in order to become a shift manager. The shift manager will be required to select an approved backup manager. The shift manager and back up will be paid $18/hr and $15/hr respectively. The shift manager and the backup cannot be absent at the same time.

Benefits will include basic health care through United health care. This is strictly medical and there is no copay as the beneficiary and their dependents will have a maximum of $3000/yr to spend on health care per year. An advantage 90 Drug Program comes with this plan which will allow the employees to obtain any prescribed generic drugs for free from all participating Walgreens. Dental insurance will also be supplied through Unicare.

1. Conceptual control Scheme
2. General Arrangement (Plant Layout)
3. Distribution and End- Use Issues review
4. Constraints Review
5. Feedstock Definition

Synthesis gas or syngas is a gaseous mixture primarily comprised of Carbon Monoxide and Hydrogen. The syngas that will be utilized by team Echo will be created from coal obtained from Illinois Coal Basin number 6. Because the syngas is coming from coal, desulfurization will need to take place as Sulfur can be harmful to catalysts. CO2 sequestion will also take place in order to have a greater purity of syngas. Coal is an abundant resource that is currently the second greatest provider of energy, coming in second only to petroleum. This coupled with projections that coal will indeed be around for at least the next two hundred years leaves hope that obtaining the necessary coal for synthesis gas will not be a problem.

Ethylene is the other portion of feedstock utilized in the synthesis of Propionaldehyde. Ethylene is currently being produced and sold at large quantities at Lyondell Basell in Morris, Il. For this reason, as is discussed in Location Sensitivity Analysis, both team Echo and Foxtrot have decided to be located there. As the location of the plant will be extremely close to this particular feedstock, the transportation constraint has been eliminated. As for the production of ethylene, it is an abundant hydrocarbon that is easily synthesized and hopefully will not be an issue in availability.

1. Conversion Technology Description

Both of our reactors will be compressed heat exchanger reactors, obtained from Chart Energy and Chemicals Inc. This specific type of reactor allows for the reaction of gas phase feeds as well as the immediate removal of heat from the system utilizing Brazed Aluminum as the reactor material. Both reactions that take place in this process to synthesize propionic acid (synthesis of propionaldehyde followed by the oxidation of the aldehyde) are highly exothermic and will require a medium to absorb all that heat in efforts to reduce the cost of energy for the plant as a whole. This specific type of reactor allows for the immediate absorption of exothermic heat which can then be used to generate steam or to increase the temperature for streams later in the process. The synthesis of the aldehyde intermediate takes place under the influence of a Rh based catalyst which will be on a solid support, to account for this, Chart Energy and Chemicals creates a specific type of the compressed heat exchanger reactor with room to place packing materials inside the open channels of the reactor. **Work in progress**

1. Separation Technology Description
2. Production Description

Propionic acid is a colorless liquid which gives off a pungent odor, chemically it is a three carbon chain carboxylic acid which has a similar density to water at ambient conditions, also this compound is miscible in water much like other short chain organic acids.

1. Location Sensitivity Analysis

The plants producing Propionic acid and syngas will be based in Morris, Il 60450. Team foxtrot based themselves in southern Illinois so as to be near Illinois coal basin number 6. As the syngas that team Foxtrot is producing is quite difficult and expensive to transport, in order to lower costs for both teams it has been decided that team Foxtrot and team Echo will be located next to each other. The determinant factor of team Echo’s location is Ethylene. Ethylene like syngas is quite expensive and difficult to transport. The region near southern Il was scoured to find ethylene production plants, and while the search lead heavily towards Texas and Louisiana eventually Lyondell Basell in Morris, Il was found and settled upon. In Morris, both teams have chosen to be located as close to a rail line as possible in order to minimize the coal transportation costs of team Foxtrot as team Foxtrot will currently be approximately 5 hours away from southern Il.

Morris, Il is a small town that is very historical yet not unwilling for progress. Not only is Morris home to Lyondell Basell and soon to be teams Echo and Foxtrot but it is also home to Dresden nuclear power plant which is one of many plants that supplies power to the Chicago land area. Bill Cheshareck is in charge of all building and zoning permits and is who must be contacted in order to determine what needs to be done in order for plants to be built in Morris.

1. ESH Law Compliance
2. Laws of Physics Compliance
3. Turndown Ratio

In order to have enough time to properly ensure that all machinery is in proper working order and to ensure that any problems can be fixed it is integral a proper turn down ratio is selected. Usual turn down ratios are around 30 days, and team echo will be going with a turn down ration of 28 days, thus the operating year will be 337 days. Team foxtrot will be operating at an 18 day turn-down ratio and thus their syngas will be stored during the 10 days in which the echo plant will not be operational.

1. Applicable Standards
2. Project Communications
3. Information Sources and References

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<http://www.lenntech.com/periodic/elements/rh.htm>

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